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Critical numeracy: helping people to decide

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Abstract: Many people skim over the quantitative material that they encounter, whether it be in the form of tables, graphs or text. Nonetheless it is important for everyone to engage with this kind of material in their everyday lives, including community lives, as a tool for learning, at work and in recreation and leisure. In the particular context of tertiary study, students need to make all kinds of decisions and judgements, many of them based on lectures and readings which contain varying amounts of quantitative material. However, many students are reluctant to engage with these kinds of materials for a number of reasons, which often include a lack of confidence. A study was undertaken with first year undergraduate students to evaluate the effectiveness of an intervention workshop based on the SOLO taxonomy and designed to give students strategies with which to interpret tables and graphs. The results showed that the students gained confidence through completing the workshop and were able to engage with the material in more depth than before. This paper describes the study and gives some analysis of the results.

Introduction

The importance of being numerate and what that entails has changed considerably over the last four decades and continues to change (Steen, 1990). People now talk about a global village with decisions about policy being made for groups of nations so that what happens in one country quickly affects another. The improvement of computers and other technologies means that the speed and ease of communication are quite staggering. In this fast moving world there are pitfalls for the unwary and, as Steen (1997) points out,

As information becomes ever more quantitative and society relies increasingly on computers and the data they produce, an innumerate citizen is as vulnerable as the illiterate peasant of Gutenberg's time. (p. xv)

The wide range of situations in which people need to be numerate include their everyday, civic and social lives as well as for lifelong learning. A large part of the lives of students at school and in further education is taken up with reading and interpreting text which often includes quantitative information (Kemp 1995; DETYA 2000). Although for some people the term 'numeracy' more or less equates to basic mathematical skills (Brown 2000; Mulligan, Bobis & Francis 1999), in this paper the term numeracy, and in particular 'critical numeracy', refers using the appropriate mathematics to interpret and understand quantitative information in tables, graphs or text. (Willis 1998). For others, terms used such as 'quantitative literacy' (Dossey 1997, Watson 2002) 'criticalmathematics' (Frankenstein 2001) or 'statistical literacy' (Watson 1995) also refer to an ability to critically evaluate the numerical aspects of a situation. The massive reach and influence of the media today makes it even more important than previously that people are able to engage with numerical information first hand and are in a position to make informed decisions, rather than relying on the possibly biased interpretations of those with a 'barrow to push'.

Much of this quantitative information is displayed in tables of data. Tables of varying degrees of complexity are included in government and statistical reports, in newspapers and in articles in academic journals. They often convey information over several years for several different categories. Tables are found in all kinds of contexts that students need to deal with in tertiary study from science to sociology to education. They are in the media for traffic statistics, water pollution, logging employment, educational achievement and so on. A typical example is shown as Table 1 below.

There is often interest in employment statistics and how these are changing. Table 1 was selected for students to examine in the present study. It was compiled by the Australian Bureau of Statistics (ABS) to show some characteristics of persons employed at home in Australia in 1989 and 1995. Tables such as this, involving various related elements, are frequently encountered in both professional and everyday settings

Table 1: A typical example of a table of quantitative information

PERSONS EMPLOYED AT HOME: SELECTED CHARACTERISTICS, APRIL 1989 AND SEPTEMBER 1995

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Occupation	April 1989			September 1995		
	Males	Females	Persons	Males	Females	Persons
Managers and administrators	116	110.2	226.2	115	99.2	214.2
Professionals	253.3	219.9	473.2	383.3	283.8	667.1
Para-professionals	34.7	72.7	107.4	36	71.6	107.6
Tradespersons	718.7	126.6	844.4	243.3	133.3	376.7
Clerks	373	1044.9	1417.9	349	1272.7	1621.3
Salespersons and personal service workers	7.1	203.3	210.4	14	343.6	486
Plant and machine operators, and drivers	1.7	37.6	39.3	3.8	66.6	104
Labourers and related workers	73.7	68	141.7	86.3	69.2	155

Taken From ABS *Persons Employed at Home* 9275.0 September 1995

People are often reluctant to look closely at the tables like these when they encounter them in text. (Chapman, Kemp & Kissane 1990). This can be partly attributed to a lack of confidence with numbers but is also probably due to a lack of skills for reading this kind of information. Close inspection of Table 1 reveals that there are a several components that need to be understood before any interpretation of trends or comparisons within categories can be made. The numbers are in thousands, the categories are broken down by gender and also given for persons, data are presented for two separate years and it is unclear what some occupations mean (eg, para-professionals and plant operators) without referring to the accompanying text. It appears from the literature and from interviews with students (Kissane 1991; Kemp & Kissane 1990) that skills associated with interpreting tables are often not taught at school and that students become more or less successful at these kinds of tasks pretty much by chance. This paper focuses on that part of numeracy which involves a willingness and ability to read and interpret tables, and how this can be fostered in tertiary students.

The study A study was conducted with first year undergraduate students at Murdoch University to look at whether a single intervention, in the form of a workshop, could influence students'

levels of responses to tables of data. There were three main parts to the study. Initially students were given a table interpretation task to complete individually. A few weeks later, they participated in a workshop and then a few more weeks later they were given a task similar to the first one to complete individually. The workshops were conducted in the normal workshop times for the students as an integral part of their course. In most cases their tutor was also present. Written responses to the tasks completed before and after the workshop were evaluated and comparisons were made between them. Any change was measured using an instrument designed as part of the study and some of the students were interviewed to find out their reactions to the intervention. The data were collected over three years, after a pilot the previous year, and the students were mainly enrolled in a Bachelor of Education program for primary teachers. Some other students from a cross curriculum unit were also part of the study in order to enable the necessary links for the statistical analysis to be made. A total of 151 students had corresponding scores, for before and after the workshop, which were used for comparison.

Table interpretation tasks

There were six tasks in all based on three tables, *Environmental Concerns*, *Suicide* and *Persons Employed at Home*, each with at least six categories measured over a two or four year period. For each table, students were required to respond to three questions, each of which was designed to elicit information about what they could interpret from the table, without being too prescriptive. The first two questions were common to all tables ('Describe the main features of the table and how the parts are related' and 'What conclusions can you draw from the table?'). In contrast, the third question had two versions ('Explain and discuss the information in the table' or **'**What societal or environmental factors might account for the data in the table?').

The workshop

The workshop introduced students to a set of strategies which can be used to read and interpret a table. The strategies were based on the SOLO taxonomy developed by Biggs and Collis (1982) and on the work of Lake (1999; 2002). These start with *getting organised*, looking at the title, headings, footnotes and source to set the scene. This is followed by looking at *what* individual numbers mean in that context. The next step is to look at *how* the numbers change, involving trends over time or comparisons to be made within categories. Then they look for *where* the numbers change, making comparisons between two or more trends or categories and start to comment on these differences. Finally the most complex step involves asking *why* the numbers change and to look for possible environmental and societal factors which influenced the changes, or for more theoretical perspectives where appropriate. For guidance within the steps the students were given specific questions about the data (Kemp & Lake 2001). It was anticipated that the students would develop the confidence and skills to extract more information from a table than they might previously have done, and to become more aware of the need to think more about the reasons and implications of the data.

At the beginning of the workshop there was general discussion about the importance of reading and understanding the data presented in tables in the media and in their study materials. The students were positive about the prospect of using strategies which would be of use to them in other contexts. The workshop activity, which took about 50 minutes, involved students reading and interpreting a table using the steps outlined above. Students worked in small groups with plenary discussion in the middle and at the end of the activity.

The measuring instrument

A measuring instrument for the level of numeracy of the student responses was also based on the SOLO taxonomy, developed by Biggs and Collis (1982) in order to interpret qualitative data of this kind. This instrument consisted of a set of criteria corresponding to the hierarchy of the strategies of the workshop. The students' extended written responses were rated according to this set of criteria. These criteria ranged from no correct response, describes table without extra information, gives some trends or comparisons, compares trends, gives reasons for the changes, makes generalizations related to the information and, finally, shows an understanding or the relevance of the information to social or economic situations. Inter-relater reliability had been

established as part of a pilot project. These ratings were subsequently coded for statistical analysis.

Analysis of the data

Direct comparison of the levels of the responses of the students before and after the workshop was not possible for two reasons. Firstly, the tasks completed before and after the workshops were not identical and secondly the responses are the results of judgements made by a rater on a scale of ordered categories. It is not statistically correct to compare the codes as numerical intervals. Before any comparisons could be made, it was necessary to obtain a set of measures of the locations of the tasks on an equal-interval scale making it legitimate to make comparisons of subsets of the data. Figure 1 summarises the resulting measures, obtained through use of the Rasch model.

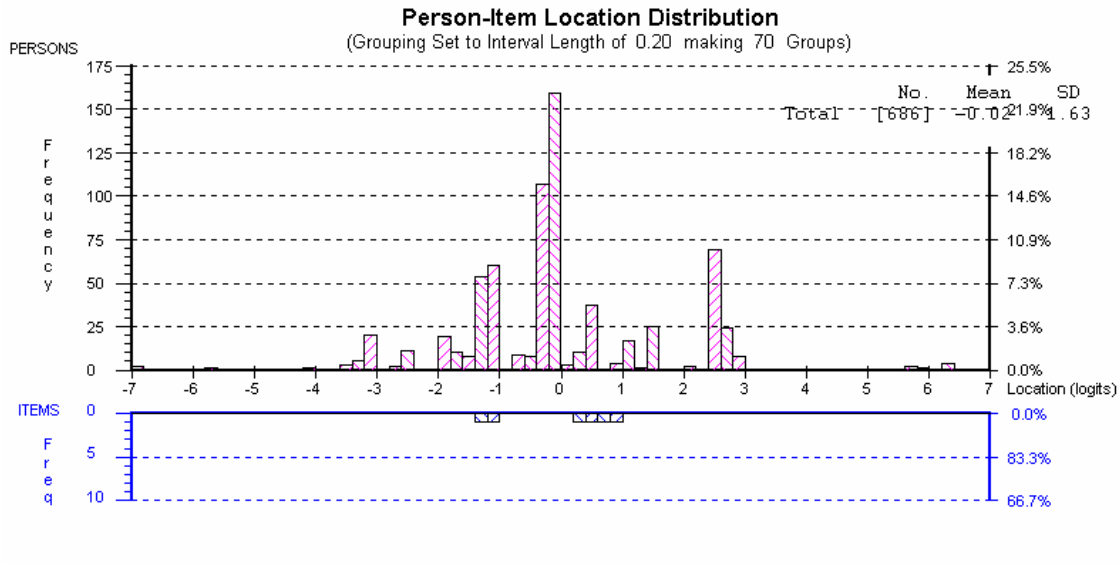

Figure 1: Person-item location distribution for the entire data set

The Rasch analysis model (Rasch 1960) is a measurement model for unidimensional data with an equal-interval scale, invariance across the people being measured and objectivity amongst the people doing the measuring. Although other types of item response theory exist, the Rasch model is the only true measurement model amongst them and so it was chosen to analyse the data using RUMM 2010. (Andrich, Sheridan & Luo 2001). This computer program takes all the data and using a probability model orders the abilities of the students and the difficulties of the items on the same scale.

For the data in this study, Figure 1 shows that, under the Rasch Model, the abilities of the students and the difficulties of the items (tasks in this case) are located on the same scale. The students exhibited quite a large ability range for these table interpretation tasks, which is consistent with informal development of the kinds of skills and thinking needed to fully interpret a table. Most of the students are located around the centre of the distribution with only a few at the extremes. It can be seen that the mean locations of the six tasks lie within the ability range of the students, which is a necessary requirement for sound measurement.

Changes in the levels of student responses

The aim of the workshop was to help students improve their ability to extract information from a table, to enable them to draw conclusions and to make inferences without direct instruction. It is one thing to be able to identify a trend when told where to look and another to independently choose to do so. The two tasks that the students were given to complete required that they made those choices themselves.

The students' written responses for the table interpretation tasks completed before and after the workshop were both evaluated using the measuring instrument. After the Rasch analysis had placed the students and items on equal interval scales a paired *t*-test was conducted to compare students responses before and after the workshop. The results of this test showed that there was a significant difference between the responses before and after the workshop ($p < 0.01$), indicating an improvement in the students' levels of numeracy. The overall change was about one unit on the scale.

Discussion and Conclusions

Early in the study some students were interviewed before and after the workshop. All of those students interviewed found the workshop helpful. One student commented:

I think there should be more workshops … its not something people do instinctively is pick up a table, they tend to look at it superficially without reading too much into it.

Another student recognised the difficulties and the role of the workshop in addressing them:

I mean a basic table is fine, but some of them get quite confusing and you don't know whether it's percentages or thousands or whatever its in relation to. This way, it's a methodical way even if you had sort of, these things here could relate to any table basically. It leads you through methodically which is probably something a lot of people wouldn't know what to do.

As shown in Figure 1, there was a fairly wide range of student responses to the tasks. This seems to reflect the comments from students that they were not taught to read a table at school at any more than a really simple level. The activity in the workshop was a new experience for them. In addition, from the interviews, it became apparent that the context of the table itself is a contributing factor to the level of engagement with a table.

The positive change in students' responses to the tasks before and after only one workshop indicates that this kind of activity might usefully be an integral part of the curriculum at both secondary school and tertiary level. The strategies could be introduced and applied to a wide variety of situations including graphs as well as tables, to develop high levels of skill in understanding quantitative information as a precursor to making informed decisions about the data presented to them.

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